Executive Summary

Water is necessary for our bodies' proper hydration, our health, and a full active life. In spaceflight, water (including quantity and quality) is a critical resource that needs to be carefully managed for crew health and safety. In the context of human spaceflight, water has a variety of uses to support crew health including hydration, food rehydration, and personal hygiene. Being well hydrated during operations is absolutely critical as dehydration can result in decrements in decision-making, concentration, and physiology of the crew. This Technical Brief focuses on the water required for human consumption during spaceflight missions.

Relevant Standards

NASA-STD-3001 Volume 1, Rev B
[V1 3003] In-Mission Preventive Health Care

NASA-STD-3001 Volume 2, Rev C
[V2 3006] Human-Centered Task Analysis
[V2 6026] Potable Water Quality
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6046] Water Quality Monitoring
[V2 6051] Water Contamination Control
[V2 7052] Stowage Location
[V2 8001] Volume Allocation
[V2 11029] LEA Suited Hydration
[V2 11030] EVA Suited Hydration

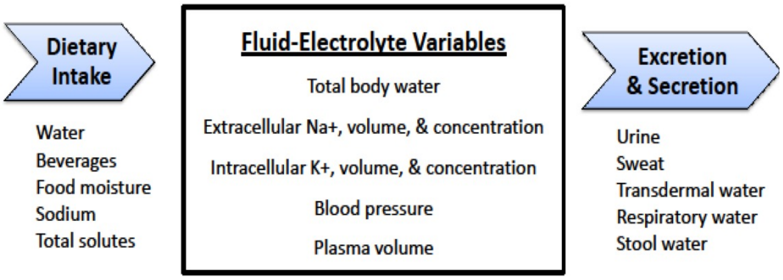
From: NASA Image and Video Library

Background

Distribution and Functions of Water

Water is found mainly inside the cells of the body, especially muscle cells. Water serves many important roles in the body including:

- Aiding in digestion and absorption of nutrients
- Carrying and distributing nutrients, metabolites, hormones, and other materials around the body and within cells
- Aiding in excretion of wastes
- Maintaining blood circulation in the body
- Maintaining body temperature
- Acting as a lubricant between bodily structures and forming mucous
- Acting as a protective shock absorber, such as for the brain
- Aiding with memory and attention



Risks of Inadequate Water System:

- Dehydration
- Renal Stones
- Orthostatic Intolerance
- Urinary Retention
- Headaches
- Abnormal Cardiac Rhythm
- Inadequate Nutritional Intake (see Food and Nutrition OCHMO Technical Brief)

A loss of 2.5% of your body weight in water will result in performance decrements, impairing decision-making and concentration, and a 35% reduction of physical performance potential. Signs and symptoms of dehydration include:

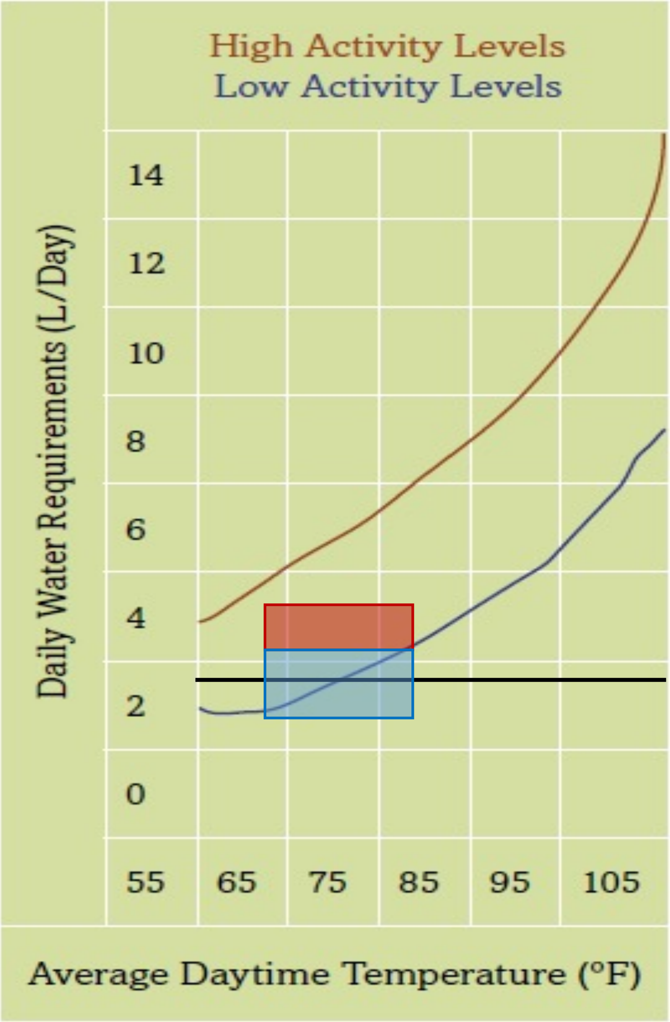
- Urine output reduced
- Reduced physical performance
- Headache and feeling ill
- Difficulty concentrating and confusion
- Sleepiness
- Temperature regulation dysfunction

The primary ways in which you may become dehydrated, or in need of additional body fluids, are by:

- Inadequate water intake
- Exercising for over 60 minutes
- Exercising or working in the heat, cold, or at altitude
- Drinking too much alcohol or caffeine
- Medications

Source: The Special Operations Forces Nutrition Guide

Background



Source: The Special Operations Forces Nutrition Guide

NASA Standards for water intake (see page 4 for details and overlay on graph):

- **2.5 L/day for direct consummation and for re-hydration of food (black line)**
- **Extra 0.24 L/hour for EVA operations (red box)**

Average Water Intake on Past Spaceflight Programs (range overlaid on graph above)

	Apollo	Skylab	Shuttle	ISS (E1-13)	ISS (E14-25)	ISS (E26-37)
# Astronauts	33*	9	32	19	19	17
Water L/day	~ 1.6 +/- 0.2	~ 2.8 +/- 0.5	~ 2.2 +/- 0.7	~ 2 +/- 0.5	~2.1 +/- 0.4	~ 2.3 +/- 0.6

- Intake includes water directly consumed and water used to rehydrate food
- For Apollo, data was only based on one mission (n of 3); assumed to be average for all missions
- E stands for Expedition, ~6 month missions on International Space Station (ISS)
- Data adapted from Human Adaptation to Spaceflight, The Role of Nutrition, Smith, Scott, M. et al, NP-2014-10-018-JSC

Reference Information

NASA-STD-3001 Volume 2 Rev C Table 4 – Water Quantities and Temperatures

Standards in **bold boxes** are the focus of this technical brief

Standard	Quantity (quantities are mutually independent)	Temperature		
		Hot	Nominal	Cold
Potable Water for Hydration	Minimum 2.5 L (84.5 fl oz) per crewmember per day *(allocation to include 600 mL per meal per crewmember to be available as Hot Water)*	between 68 ºC (155 ºF) and 79 ºC (175 ºF) **	between 18 ºC (64 ºF) and 27 ºC (80.6 ºF)	maximum temperature of 16 ºC (60 ºF)
Potable Water Quantity for Personal Hygiene	Mission dependent	between 29 ºC (85 ºF) and 46 ºC (115 ºF)		
Potable Water Quantity for Eye Irrigation	Minimum 500 mL (16.9 fl oz) per crewmember	between 18 ºC (64.4 ºF) and 27 ºC (80.6 ºF)		
Potable Water for Medical Use and Medical Contingency	Minimum of 5 L (169.1 fl oz) per event			
Potable Water for EVA Operations	Minimum 240 mL (8.1 fl oz) per EVA hour			
Potable Water for Fluid Loading for Re-Entry from Microgravity to Earth Gravity	Minimum of 1 L (33.8 fl oz) per crewmember	between 68 ºC (155 ºF) and 79 ºC (175 ºF)	between 18 ºC (64.ºF) and 27 ºC (81 ºF)	maximum temperature of 16 ºC (60 ºF)
Potable Water for Crew Recovery During Entire Recovery Period	Minimum of 1 L (33.8 fl oz) per crewmember for every 8-hour period			
Sampling Water Quantity	Mission dependent ***	N/A		
Agriculture Water Quantity	Mission dependent ***	TBD		

*** Critical for missions longer than three days.*

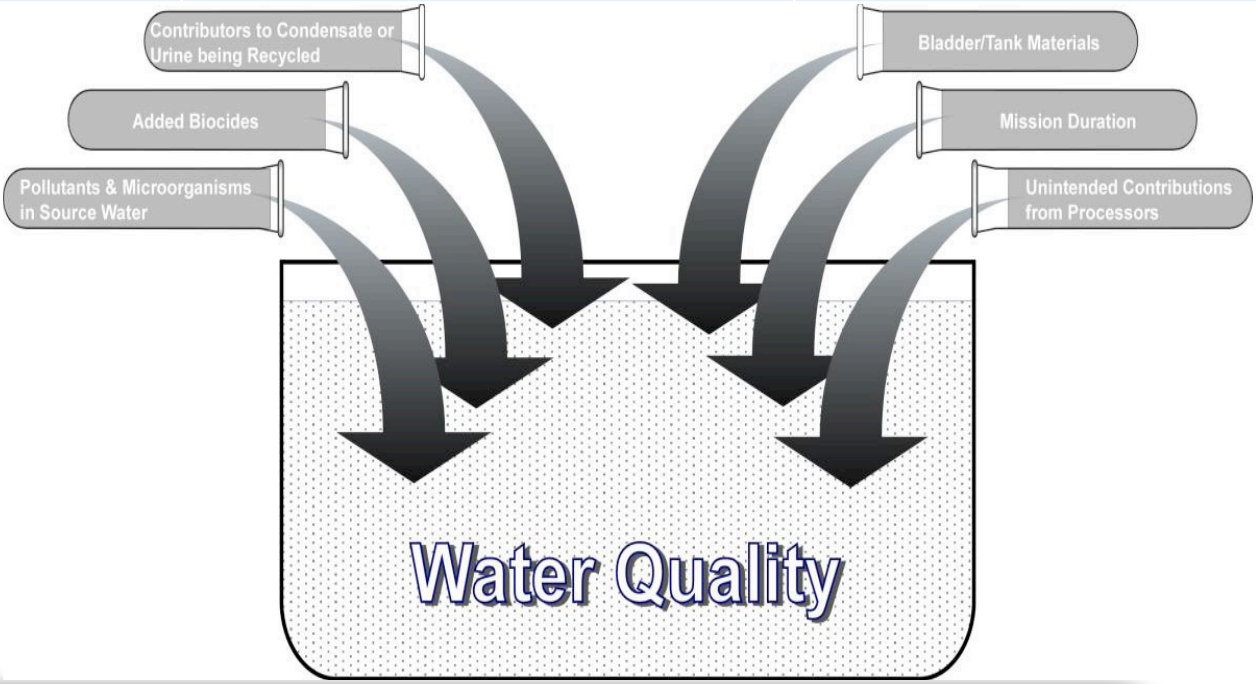
**** Mission dependent as sized by appropriate sampling or plant science personnel.*

†† The bulk supply of water should be accessible as ambient and/or cold.

Reference Information

Human Integration Design Handbook
Table 6.3-1 Water Chemical Contamination Sources

Water Contamination Source	Contamination Process	Specific Contaminants
Contamination of Ground-Supplied Water	• Present in the source water • Introduced unintentionally during processing • Derived from the material that comprises the bladder and/or on-orbit delivery tank, or is transferred by a dispensing system	
In-Flight Contamination	• Recycled humidity condensate may contain water-soluble chemicals that are transferred from the spacecraft atmosphere	• Contaminants from a diversity of chemical-containing spacecraft payloads and materials (Schultz et al., 2006) • Airborne microbes, chemicals
	• Human metabolic products	• Organic acids and esters • Pharmaceutical agents • Drug metabolism byproducts • Menses • Tissue sloughing
Compounds Purposely Added to Spacecraft Water	• Compounds that are purposely added to spacecraft water	• Iodine or silver added because of the biocidal properties • Minerals (e.g., calcium, magnesium) to improve palatability or offer dietary enhancement



Application Notes

Water Supply – Water must be safe, acceptable, and able to meet mission requirements.

Considerations

- How to supply sufficient water quantity (sources) – producing by means of fuel cells, in situ resource utilization, or recycling water (hygiene water, urine, humidity).
- Processing of urine needs to account for the excess calcium that is excreted by the body in spaceflight.
- Access for water sampling before, during, and after flight – access should be provided as late as possible before launch, and as soon as possible after landing.
- Flow rate and quantity of water dispensing – for the crew to be able to prepare for and perform tasks that require potable water in a reasonable amount of time; to prevent overflow, water must be dispensable in specified increments that are compatible with the food and drink bags.
- For fluid loading, 1.5L of water per crewmember is based on the Space Shuttle and CCP prescriptions for re-entry fluid loading. The table on Page 4 calls out a minimum of 1000mL of water per crewmember and an additional 500 mL will be available per crewmember from their unused daily water allocation. Vehicles that may wave off prior to re-entry need to protect for two fluid loadings per crewmember. Fluid loading is based on crewmember weight and requires the use of salt tablets in addition to water, unless an alternative solution is used. Without fluid loading the crew is more likely to experience orthostatic intolerance (passing out when standing) during and after deorbit.

Technical Challenges

- Production of water (in-flight vs. recycling vs. supplied)
- Stowage
- Shelf-life
- Dispensing capabilities

Mission Requirements – Missions up to three days in length may have mass and power constraints that do not support certain types of water, such as urine reclamation or recycling. As mission length increases (> that 30 days), water supply sources may need to be reconsidered to appropriately provide the needs to crew while considering mass constraints.

Development of Potable Water System – Consideration for safety and acceptability, as well as:

- **Storage duration** (based on mission duration plus the time required to process, test, and ship the water for launch) and **shelf life** (based on water preparation method).
- **Packaging type** is essential for maintaining safety and acceptability throughout shelf life – water packaging must meet safety and gaseous pollutant specifications.
- **Suitability for use in microgravity**, for example, dispensing of the water into water containers will need to be considered in both microgravity and partial gravity environments.

Temperature Availability – having the ability to provide not only ambient temperature water, but access to hot and cold water should be considered for crew personal preference, as well as supporting the psychological benefits for options to the crew during isolation from home.

Expertise – NASA utilizes the following expertise to develop and provide a food system:

- **Toxicologists** ensure water quality throughout development and testing process.
- **Packaging engineers** develop and test package integrity (sealing and vacuum) of packaged water.
- **Logistics specialists** develop stowage procedures and monitor water inventory.
- **Facilities** – Proper facilities to ensure the water is free of contamination prior to launch including analytical labs for testing.

Back-Up

Major Changes Between Revisions

Rev A → Rev B

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev B and Volume 2 Rev C.
- Slide 4: Updated table for current values

Original → Rev A

- Slide 4: Added a footnote regarding potable water amounts for fluid loading
- Slide 6: Added a bullet under Considerations regarding potable water amounts for fluid loading

Referenced Standards

NASA-STD-3001 Volume 1 Revision B

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA) that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. The term "in-mission" covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).

NASA-STD-3001 Volume 2 Revision C

[V2 3006] Human-Centered Task Analysis Each human space flight program or project shall perform a human-centered task analysis to support systems and operations design.

[V2 6026] Potable Water Quality At the point of crew consumption or contact, the system shall provide aesthetically acceptable potable water that is chemically and microbiologically safe for human use, including drinking, food rehydration, personal hygiene, and medical needs.

[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 4, Water Quantities and Temperatures, for the expected needs of each mission, which should be considered mutually independent.

[V2 6110] Water Temperature The system shall provide the appropriate water temperature as specified in Table 4, Water Quantities and Temperatures, for the expected needs of each mission and task.

[V2 6039] Water Dispensing Rate Water shall be dispensed at a rate that is compatible with the food system.

[V2 6040] Water Dispensing Increments To prevent overflow, water shall be dispensable in specified increments that are compatible with the food preparation instructions and time demands of the allotted meal schedule.

[V2 6046] Water Quality Monitoring Water quality monitoring capability shall include preflight, in-flight, and post landing sampling and analysis.

[V2 6051] Water Contamination Control The system shall prevent potable and hygiene water supply contamination from microbial, atmospheric (including dust), chemical, and non-potable water sources to ensure that potable and hygiene water are provided.

[V2 7052] Stowage Location All relocatable items, e.g., food, EVA suits, and spare parts, shall have a dedicated stowage location.

[V2 8001] Volume Allocation The system shall provide the defined habitable volume and layout to physically accommodate crew operations and living.

[V2 11029] LEA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 2 L (67.6 fl oz) per 24 hours for the LEA suit.

[V2 11030] EVA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 240 mL (8.1 fl oz) per hour for EVA suited operations.

Reference List

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Other Standards for Consideration
[V2 3006] Human-Centered Task Analysis[1]
[V2] 7052 Stowage Location
[V2 8001] Volume Allocation
1. Human-Centered Task & Error Analysis Technical Brief